(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 October 2004 (28.10.2004)

PCT

(10) International Publication Number
WO 2004/092833 A2

(51) International Patent Classification[7]: G03F

(21) International Application Number: PCT/US2004/009994

(22) International Filing Date: 1 April 2004 (01.04.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/462,112 10 April 2003 (10.04.2003) US
60/485,033 2 July 2003 (02.07.2003) US

(71) Applicant (*for all designated States except US*): **NIKON CORPORATION** [JP/JP]; 2-3, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-8331 (JP).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **NOVAK, Thomas, W.** [US/US]; 1205 Lakeview Drive, Hillsborough, CA 94010 (US). **HAZELTON, Andrew, J.** [US/US]; 409 Phelps Road, San Carlos, CA 94070 (US). **WATSON, Douglas, C.** [US/US]; 1353 Camco Drive, Campbell, CA 95008 (US).

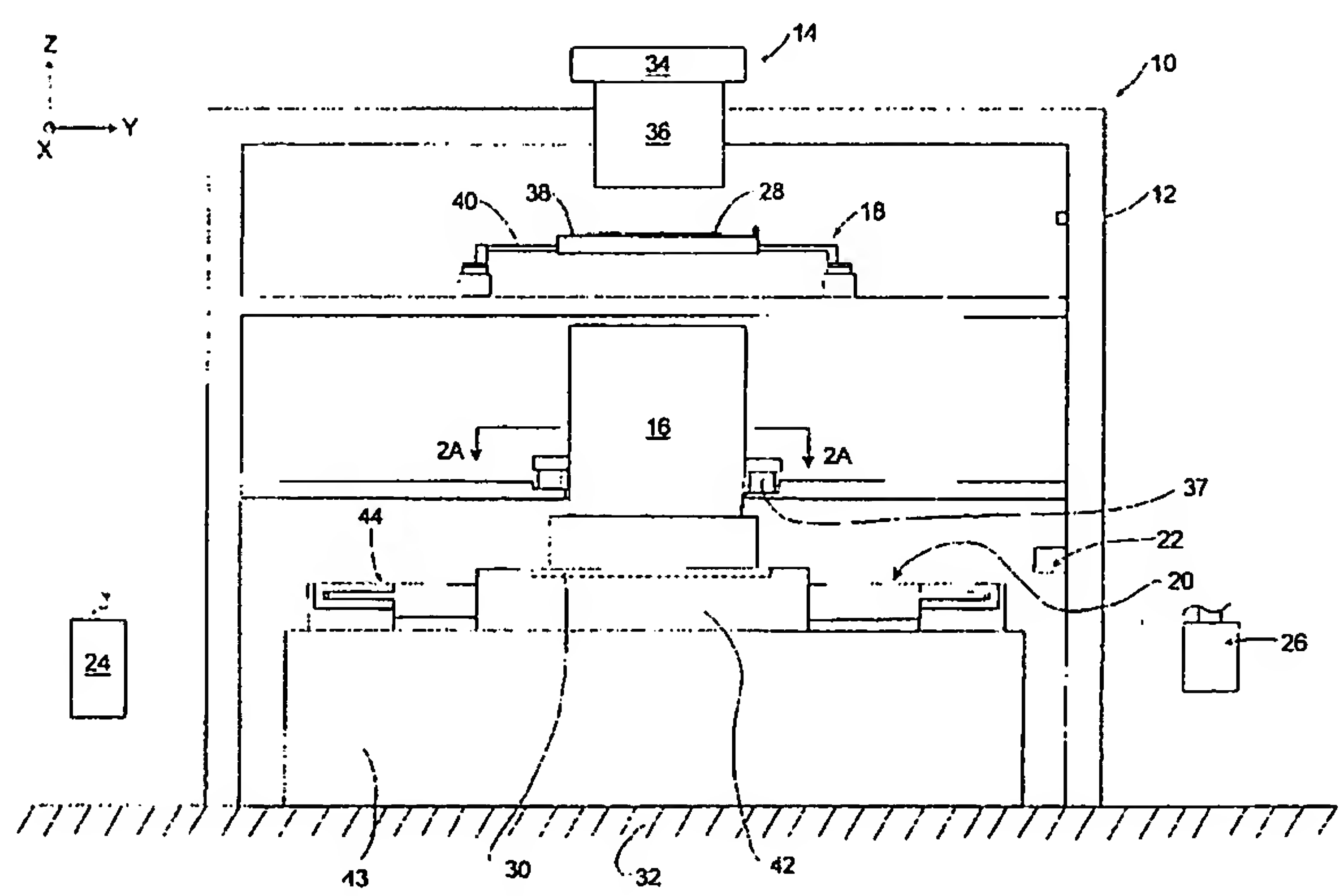
(74) Agent: **ROEDER, Steven, G.**; The Law Office of Steven G. Roeder, 5560 Chelsea Avenue, La Jolla, CA 92037 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: ENVIRONMENTAL SYSTEM INCLUDING A TRANSPORT REGION FOR AN IMMERSION LITHOGRAPHY APPARATUS



(57) Abstract: An environmental system (26) for controlling an environment in a gap (246) between an optical assembly (16) and a device (30) includes a fluid barrier (254), an immersion fluid system (252), and a transport region (256). The fluid barrier (254) is positioned near the device (30) and maintains the transport region (256) near the gap (246). The immersion fluid system (252) delivers an immersion fluid (248) that fills the gap (246). The transport region (256) transports at least a portion of the immersion fluid (248) that is near the fluid barrier (254) and the device (30) away from the device (30). The immersion fluid system (252) can include a fluid removal system (282) that is in fluid communication with the transport region (256). The transport region (256) can be made of a porous material.

WO 2004/092833 A2

Published:
— *without international search report and to be republished upon receipt of that report*

UNITED STATES PATENT APPLICATION

of

W. THOMAS NOVAK, ANDREW J. HAZELTON, AND DOUGLAS C. WATSON

for

ENVIRONMENTAL SYSTEM INCLUDING A TRANSPORT REGION FOR AN IMMERSION LITHOGRAPHY APPARATUS

RELATED APPLICATIONS

This application claims priority on Provisional Application Serial No. 60/462,112 filed on April 10, 2003 and entitled "VACUUM RING SYSTEM AND WICK RING SYSTEM FOR IMMERSION LITHOGRAPHY"; and Provisional Application Serial No. 60/485,033 filed on July 2, 2003 and entitled "MULTIPLE CONCENTRIC ARRANGEMENT OF PUMPS AND WICKS AROUND PERIPHERY OF LENS TO REMOVE AND INSPECT IMMERSION LIQUID FOR IMMERSION LITHOGRAPHY". As far as is permitted, the contents of Provisional Application Serial Nos. 60/462,112, and 60/485,033 are incorporated herein by reference.

BACKGROUND

Exposure apparatuses are commonly used to transfer images from a reticle onto a semiconductor wafer during semiconductor processing. A typical exposure apparatus includes an illumination source, a reticle stage assembly that positions a reticle, an optical assembly, a wafer stage assembly that positions a semiconductor wafer, and a measurement system that precisely monitors the position of the reticle and the wafer.

Immersion lithography systems utilize a layer of immersion fluid that fills a gap between the optical assembly and the wafer. The wafer is moved rapidly in a typical lithography system and it would be expected to carry the immersion fluid

away from the gap. This immersion fluid that escapes from the gap can interfere with the operation of other components of the lithography system. For example, the immersion fluid can interfere with the measurement system that monitors the position of the wafer.

SUMMARY

The present invention is directed to an environmental system for controlling an environment in a gap between an optical assembly and a device that is retained by a device stage. The environmental system includes an immersion fluid source and a transport region that is positioned near the device. The immersion fluid source delivers an immersion fluid that enters the gap. The transport region captures immersion fluid that is exiting the gap. With this design, in certain embodiments, the invention avoids the use of direct vacuum suction on the device that could potentially distort the device and/or the optical assembly.

In one embodiment, the environmental system includes a fluid barrier that is positioned near the device and that encircles the gap. Furthermore, the fluid barrier can maintain the transport region near the device.

In one embodiment, the environmental system includes a fluid removal system that removes immersion fluid from near the transport region. In another embodiment, the fluid removal system can direct a removal fluid that removes immersion fluid from the transport region. In this embodiment, the removal fluid can be at a removal fluid temperature that is higher than an immersion fluid temperature of the immersion fluid.

In one embodiment, the transport region is a substrate that includes a plurality of passages for collecting the immersion fluid near the transport region. As an example, the transport region can be made of a material that conveys the immersion fluid by capillary action. In this embodiment, the passages can be a plurality of pores. In an alternative embodiment, the passages can be a plurality of spaced apart transport apertures that extend through the transport region.

The present invention is also directed to an exposure apparatus, a wafer, a device, a method for controlling an environment in a gap, a method for making an exposure apparatus, a method for making a device, and a method for manufacturing a wafer.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a side illustration of an exposure apparatus having features of the present invention;

Figure 2A is a perspective view of a portion of the exposure apparatus of Figure 1;

Figure 2B is a cut-away view taken on line 2B-2B of Figure 2A;

Figure 2C is an enlarged detailed view taken on line 2C-2C in Figure 2B;

Figure 2D is an enlarged detailed view of another embodiment of a portion of an exposure apparatus;

Figure 3A is a side illustration of an immersion fluid source having features of the present invention;

Figure 3B is a side illustration of a fluid removal system having features of the present invention;

Figure 3C is a side illustration of another embodiment of a fluid removal system having features of the present invention;

Figure 3D is a side illustration of yet another embodiment of a fluid removal system having features of the present invention;

Figure 4 is an enlarged cut-away view of a portion of another embodiment of an exposure apparatus;

Figure 5A is an enlarged cut-away view of a portion of yet another embodiment of an exposure apparatus;

Figure 5B is an enlarged detailed view taken on line 5B-5B in Figure 5A;

Figure 6A is a flow chart that outlines a process for manufacturing a device in accordance with the present invention; and

Figure 6B is a flow chart that outlines device processing in more detail.

DESCRIPTION

Figure 1 is a schematic illustration of a precision assembly, namely an exposure apparatus 10 having features of the present invention. The exposure apparatus 10 includes an apparatus frame 12, an illumination system 14 (irradiation apparatus), an optical assembly 16, a reticle stage assembly 18, a

device stage assembly 20, a measurement system 22, a control system 24, and a fluid environmental system 26. The design of the components of the exposure apparatus 10 can be varied to suit the design requirements of the exposure apparatus 10.

A number of Figures include an orientation system that illustrates an X axis, a Y axis that is orthogonal to the X axis, and a Z axis that is orthogonal to the X and Y axes. It should be noted that these axes can also be referred to as the first, second and third axes.

The exposure apparatus 10 is particularly useful as a lithographic device that transfers a pattern (not shown) of an integrated circuit from a reticle 28 onto a semiconductor wafer 30 (illustrated in phantom). The wafer 30 is also referred to generally as a device, or work piece. The exposure apparatus 10 mounts to a mounting base 32, e.g., the ground, a base, or floor or some other supporting structure.

There are a number of different types of lithographic devices. For example, the exposure apparatus 10 can be used as a scanning type photolithography system that exposes the pattern from the reticle 28 onto the wafer 30 with the reticle 28 and the wafer 30 moving synchronously. In a scanning type lithographic apparatus, the reticle 28 is moved perpendicularly to an optical axis of the optical assembly 16 by the reticle stage assembly 18 and the wafer 30 is moved perpendicularly to the optical axis of the optical assembly 16 by the wafer stage assembly 20. Scanning of the reticle 28 and the wafer 30 occurs while the reticle 28 and the wafer 30 are moving synchronously.

Alternatively, the exposure apparatus 10 can be a step-and-repeat type photolithography system that exposes the reticle 28 while the reticle 28 and the wafer 30 are stationary. In the step and repeat process, the wafer 30 is in a constant position relative to the reticle 28 and the optical assembly 16 during the exposure of an individual field. Subsequently, between consecutive exposure steps, the wafer 30 is consecutively moved with the wafer stage assembly 20 perpendicularly to the optical axis of the optical assembly 16 so that the next field of the wafer 30 is brought into position relative to the optical assembly 16 and the reticle 28 for exposure. Following this process, the images on the reticle 28 are sequentially exposed onto the fields of the wafer 30, and then the next field of the

wafer 30 is brought into position relative to the optical assembly 16 and the reticle 28.

However, the use of the exposure apparatus 10 provided herein is not limited to a photolithography system for semiconductor manufacturing. The exposure apparatus 10, for example, can be used as an LCD photolithography system that exposes a liquid crystal display device pattern onto a rectangular glass plate or a photolithography system for manufacturing a thin film magnetic head.

The apparatus frame 12 supports the components of the exposure apparatus 10. The apparatus frame 12 illustrated in Figure 1 supports the reticle stage assembly 18, the wafer stage assembly 20, the optical assembly 16 and the illumination system 14 above the mounting base 32.

The illumination system 14 includes an illumination source 34 and an illumination optical assembly 36. The illumination source 34 emits a beam (irradiation) of light energy. The illumination optical assembly 36 guides the beam of light energy from the illumination source 34 to the optical assembly 16. The beam illuminates selectively different portions of the reticle 28 and exposes the wafer 30. In Figure 1, the illumination source 34 is illustrated as being supported above the reticle stage assembly 18. Typically, however, the illumination source 34 is secured to one of the sides of the apparatus frame 12 and the energy beam from the illumination source 34 is directed to above the reticle stage assembly 18 with the illumination optical assembly 36.

The illumination source 34 can be a g-line source (436 nm), an i-line source (365 nm), a KrF excimer laser (248 nm), an ArF excimer laser (193 nm) or a F_2 laser (157 nm). Alternatively, the illumination source 34 can generate charged particle beams such as an x-ray or an electron beam. For instance, in the case where an electron beam is used, thermionic emission type lanthanum hexaboride (LaB_6) or tantalum (Ta) can be used as a cathode for an electron gun. Furthermore, in the case where an electron beam is used, the structure could be such that either a mask is used or a pattern can be directly formed on a substrate without the use of a mask.

The optical assembly 16 projects and/or focuses the light passing through the reticle 28 to the wafer 30. Depending upon the design of the exposure apparatus 10, the optical assembly 16 can magnify or reduce the image

illuminated on the reticle 28. The optical assembly 16 need not be limited to a reduction system. It could also be a 1x or magnification system.

When far ultra-violet rays such as the excimer laser is used, glass materials such as quartz and fluorite that transmit far ultra-violet rays can be used in the optical assembly 16. When the F_2 type laser or x-ray is used, the optical assembly 16 can be either catadioptric or refractive (a reticle should also preferably be a reflective type), and when an electron beam is used, electron optics can consist of electron lenses and deflectors. The optical path for the electron beams should be in a vacuum.

Also, with an exposure device that employs vacuum ultra-violet radiation (VUV) of wavelength 200 nm or lower, use of the catadioptric type optical system can be considered. Examples of the catadioptric type of optical system include the disclosure Japan Patent Application Disclosure No.8-171054 published in the Official Gazette for Laid-Open Patent Applications and its counterpart U.S. Patent No, 5,668,672, as well as Japan Patent Application Disclosure No.10-20195 and its counterpart U.S. Patent No. 5,835,275. In these cases, the reflecting optical device can be a catadioptric optical system incorporating a beam splitter and concave mirror. Japan Patent Application Disclosure No.8-334695 published in the Official Gazette for Laid-Open Patent Applications and its counterpart U.S. Patent No. 5,689,377 as well as Japan Patent Application Disclosure No.10-3039 and its counterpart U.S. Patent Application No. 873,605 (Application Date: 6-12-97) also use a reflecting-refracting type of optical system incorporating a concave mirror, etc., but without a beam splitter, and can also be employed with this invention. As far as is permitted, the disclosures in the above-mentioned U.S. patents, as well as the Japan patent applications published in the Official Gazette for Laid-Open Patent Applications are incorporated herein by reference.

In one embodiment, the optical assembly 16 is secured to the apparatus frame 12 with one or more optical mount isolators 37. The optical mount isolators 37 inhibit vibration of the apparatus frame 12 from causing vibration to the optical assembly 16. Each optical mount isolator 37 can include a pneumatic cylinder (not shown) that isolates vibration and an actuator (not shown) that isolates vibration and controls the position with at least two degrees of motion. Suitable optical mount isolators 37 are sold by Integrated Dynamics Engineering, located in Woburn, MA. For ease of illustration, two spaced apart optical mount isolators 37

are shown as being used to secure the optical assembly 16 to the apparatus frame 12. However, for example, three spaced apart optical mount isolators 37 can be used to kinematically secure the optical assembly 16 to the apparatus frame 12.

The reticle stage assembly 18 holds and positions the reticle 28 relative to the optical assembly 16 and the wafer 30. In one embodiment, the reticle stage assembly 18 includes a reticle stage 38 that retains the reticle 28 and a reticle stage mover assembly 40 that moves and positions the reticle stage 38 and reticle 28.

Somewhat similarly, the device stage assembly 20 holds and positions the wafer 30 with respect to the projected image of the illuminated portions of the reticle 28. In one embodiment, the device stage assembly 20 includes a device stage 42 that retains the wafer 30, a device stage base 43 that supports and guides the device stage 42, and a device stage mover assembly 44 that moves and positions the device stage 42 and the wafer 28 relative to the optical assembly 16 and the device stage base 43. The device stage 42 is described in more detail below.

Each stage mover assembly 40, 44 can move the respective stage 38, 42 with three degrees of freedom, less than three degrees of freedom, or more than three degrees of freedom. For example, in alternative embodiments, each stage mover assembly 40, 44 can move the respective stage 38, 42 with one, two, three, four, five or six degrees of freedom. The reticle stage mover assembly 40 and the device stage mover assembly 44 can each include one or more movers, such as rotary motors, voice coil motors, linear motors utilizing a Lorentz force to generate drive force, electromagnetic movers, planar motors, or some other force movers.

In photolithography systems, when linear motors (see US Patent Numbers 5,623,853 or 5,528,118) are used in the wafer stage assembly or the reticle stage assembly, the linear motors can be either an air levitation type employing air bearings or a magnetic levitation type using Lorentz force or reactance force. Additionally, the stage could move along a guide, or it could be a guideless type stage that uses no guide. As far as is permitted, the disclosures in US Patent Numbers 5,623,853 and 5,528,118 are incorporated herein by reference.

Alternatively, one of the stages could be driven by a planar motor, which drives the stage by an electromagnetic force generated by a magnet unit having two-dimensionally arranged magnets and an armature coil unit having two-dimensionally arranged coils in facing positions. With this type of driving system, either the magnet unit or the armature coil unit is connected to the stage base and the other unit is mounted on the moving plane side of the stage.

Movement of the stages as described above generates reaction forces that can affect performance of the photolithography system. Reaction forces generated by the wafer (substrate) stage motion can be mechanically transferred to the floor (ground) by use of a frame member as described in US Patent No. 5,528,100 and published Japanese Patent Application Disclosure No. 8-136475. Additionally, reaction forces generated by the reticle (mask) stage motion can be mechanically transferred to the floor (ground) by use of a frame member as described in US Patent No. 5,874,820 and published Japanese Patent Application Disclosure No. 8-330224. As far as is permitted, the disclosures in US Patent Numbers 5,528,100 and 5,874,820 and Japanese Patent Application Disclosure No. 8-330224 are incorporated herein by reference.

The measurement system 22 monitors movement of the reticle 28 and the wafer 30 relative to the optical assembly 16 or some other reference. With this information, the control system 24 can control the reticle stage assembly 18 to precisely position the reticle 28 and the device stage assembly 20 to precisely position the wafer 30. The design of the measurement system 22 can vary. For example, the measurement system 22 can utilize multiple laser interferometers, encoders, mirrors, and/or other measuring device.

The control system 24 receives information from the measurement system 22 and controls the stage mover assemblies 18, 20 to precisely position the reticle 28 and the wafer 30. Additionally, the control system 24 can control the operation of the components of the environmental system 26. The control system 24 can include one or more processors and circuits.

The environmental system 26 controls the environment in a gap 246 (illustrated in Figure 2B) between the optical assembly 16 and the wafer 30. The gap 246 includes an imaging field. The imaging field includes the area adjacent to the region of the wafer 30 that is being exposed and the area in which the beam of light energy travels between the optical assembly 16 and the wafer 30. With this

design, the environmental system 26 can control the environment in the imaging field.

The desired environment created and/or controlled in the gap 246 by the environmental system 26 can vary accordingly to the wafer 30 and the design of the rest of the components of the exposure apparatus 10, including the illumination system 14. For example, the desired controlled environment can be a fluid such as water. Alternatively, the desired controlled environment can be another type of fluid.

Figure 2A is a perspective view of the wafer 30, and a portion of the exposure apparatus 10 of Figure 1 including the optical assembly 16, the device stage 42, and the environmental system 26.

Figure 2B is a cut-away view of the portion of the exposure apparatus 10 of Figure 2A, including the optical assembly 16, the device stage 42, and the environmental system 26. Figure 2B illustrates that the optical assembly 16 includes an optical housing 250A, a last optical element 250B, and an element retainer 250C that secures the last optical element 250B to the optical housing 250A. Additionally, Figure 2B illustrates the gap 246 between the last optical element 250B and the wafer 30. In one embodiment, the gap 246 is approximately 1mm.

In one embodiment, the environmental system 26 fills the imaging field and the rest of the gap 246 with an immersion fluid 248 (illustrated as circles). The design of the environmental system 26 and the components of the environmental system 26 can be varied. In the embodiment illustrated in Figure 2B, the environmental system 26 includes an immersion fluid system 252, a fluid barrier 254, and a transport region 256. In this embodiment, (i) the immersion fluid system 252 delivers and/or injects the immersion fluid 248 into the gap 246, removes the immersion fluid 248 from or near the transport region 256, and/or facilitates the movement of the immersion fluid 248 through the transport region 256, (ii) the fluid barrier 254 inhibits the flow of the immersion fluid 248 away from near the gap 246, and (iii) the transport region 256 transfers and/or conveys the immersion fluid 248 flowing from the gap 246. The fluid barrier 254 also forms a chamber 257 near the gap 246.

The design of the immersion fluid system 252 can vary. For example, the immersion fluid system 252 can inject the immersion fluid 248 at one or more

locations at or near the gap 246 and chamber 257, the edge of the optical assembly 16, and/or directly between the optical assembly 16 and the wafer 30. Further, the immersion fluid system 252 can assist in removing and/or scavenging the immersion fluid 248 at one or more locations at or near the device 30, the gap 246 and/or the edge of the optical assembly 16.

In the embodiment illustrated in Figure 2B, the immersion fluid system 252 includes one or more injector nozzles 258 (only one is illustrated) positioned near the perimeter of the optical assembly 16 and an immersion fluid source 260. Figure 2C illustrates one injector nozzle 258 in more detail. In this embodiment, each of the injector nozzles 258 includes a nozzle outlet 262 that is in fluid communication with the immersion fluid source 260. At the appropriate time, the immersion fluid source 260 provides immersion fluid 248 to the one or more nozzle outlets 262 that is released into the chamber 257.

Figures 2B and 2C also illustrate that the immersion fluid 248 in the chamber 257 sits on top of the wafer 30. The immersion fluid 248 flows into the gap 246. Further, as the wafer 30 moves under the optical assembly 16, it will drag the immersion fluid 248 in the vicinity of the top surface of the wafer 30 with the wafer 30 into the gap 246.

In one embodiment, the fluid barrier 254 forms the chamber 257 around the gap 246, restricts the flow of the immersion fluid 248 from the gap 246, assists in maintaining the gap 246 full of the immersion fluid 248, and facilitates the recovery of the immersion fluid 248 that escapes from the gap 246. In one embodiment, the fluid barrier 254 encircles and is positioned entirely around the gap 246 and the bottom of the optical assembly 16. Further, in one embodiment, the fluid barrier 254 confines the immersion fluid 248 to a region on the wafer 30 and the device stage 42 centered on the optical assembly 16. Alternatively, for example, the fluid barrier 254 can be positioned around only a portion of the gap 246 or the fluid barrier 254 can be off-center of the optical assembly 16.

In the embodiment illustrated in Figures 2B and 2C, the fluid barrier 254 includes a containment frame 264, and a frame support 268. In this embodiment, the containment frame 264 is generally annular ring shaped and encircles the gap 246. Additionally, in this embodiment, the containment frame 264 includes a top side 270A, an opposed bottom side 270B that faces the wafer 30, an inner side 270C that faces the gap 246, and an outer side 270D. Moreover, in this

embodiment, the fluid barrier 254 includes a channel 272 for receiving the transport region 256. As an example, the channel 272 can be annular shaped.

It should be noted that the terms top and bottom are used merely for convenience and the orientation of the containment frame 264 can be rotated. It should also be noted that the containment frame 264 can have another shape. For example, the containment frame 264 can be rectangular frame shaped, octagonal frame shaped, oval frame shaped, or another suitable shape.

The frame support 268 connects and supports the containment frame 264 to the apparatus frame 12, another structure, and/or the optical assembly 16, above the wafer 30 and the device stage 42. In one embodiment, the frame support 268 supports all of the weight of the containment frame 264. Alternatively, for example, the frame support 268 can support only a portion of the weight of the containment frame 264. In one embodiment, the frame support 268 can include one or more support assemblies 274. For example, the frame support 268 can include three spaced apart support assemblies 274 (only two are illustrated in Figure 2B). In this embodiment, each support assembly 274 extends between the optical assembly 16 and the inner side 270C of the containment frame 264.

In one embodiment, each support assembly 274 is a mount that rigidly secures the containment frame 264 to the optical assembly 16. Alternatively, for example, each support assembly can be a flexure that supports the containment frame 264 in a flexible fashion. As used herein, the term "flexure" shall mean a part that has relatively high stiffness in some directions and relatively low stiffness in other directions. In one embodiment, the flexures cooperate (i) to be relatively stiff along the X axis and along the Y axis, and (ii) to be relatively flexible along the Z axis. In this embodiment, the flexures can allow for motion of the containment frame 264 along the Z axis and inhibit motion of the containment frame 264 along the X axis and the Y axis.

Alternatively, for example, each support assembly 274 can be an actuator that can be used to adjust the position of the containment frame 264 relative to the wafer 30 and the device stage 42. In this embodiment, the frame support 268 can also include a frame measurement system (not shown) that monitors the position of the containment frame 264. For example, the frame measurement system can monitor the position of the containment frame 264 along the Z axis, about the X

axis, and/or about the Y axis. With this information, the support assemblies 274 can be used to adjust the position of the containment frame 264. In this embodiment, the support assemblies 274 can actively adjust the position of the containment frame 264.

Figures 2B and 2C also illustrate the transport region 256 in more detail. In this embodiment, the transport region 256 is a substrate 275 that is substantially annular disk shaped, encircles the gap 246, and is substantially concentric with the optical assembly 16. Alternatively, for example, the substrate 275 can be another shape, including oval frame shaped, rectangular frame shaped or octagonal frame shaped. Still alternatively, for example, the transport region 256 can include a plurality of substrate segments that cooperate to encircle a portion of the gap 246, and/or a plurality of substantially concentric substrates.

The dimensions of the transport region 256 can be selected to achieve the desired immersion fluid recovery rate.

Further, in this embodiment, the transport region 256 is secured to the containment frame 264 at or near the bottom side 270B of the containment frame 264 and cooperates with the containment frame 264 to form a removal chamber 276 next to and above the transport region 256. Moreover, as illustrated in Figure 2C, the transport region 256 includes a first surface 278A that is adjacent the removal chamber 276 and an opposed second surface 278B is adjacent to the device 30 and the gap 246.

In this embodiment, the transport region 256 captures, retains, and/or absorbs at least a portion of the immersion fluid 248 that flows between the containment frame 264 and the wafer 30 and/or the device stage 42. The type of material utilized in the transport region 256 can vary. In one embodiment, the substrate 275 includes a plurality of passages 280. For example, the passages 280 can be relatively small and tightly packed.

As an example, the transport region 256 can be a porous material having a plurality of pores and/or interstices that convey the immersion fluid 248 by capillary action. In this embodiment, the passages 280 can be small enough so that capillary forces draw the immersion fluid 248 into the pores. Examples of suitable materials include wick type structures made of metals, glasses, or ceramics. Examples of suitable wick type structures include any material with a network of interconnected, small passages, including, but not limited to, woven

fiberglass, sintered metal powders, screens, wire meshes, or grooves in any material. The transport region 256 can be hydrophilic.

In one embodiment, the transport region 256 has a pore size of between approximately 20 and 200 microns. In alternative, non-exclusive embodiments, the transport region 256 can have a porosity of at least approximately 40, 80, 100, 140, 160 or 180.

In certain embodiments, a relatively higher flow capacity is required. To accommodate higher flow, larger porosity material may be necessary for the transport region 256. The choice for the porosity of the transport region 256 depends on the overall flow rate requirement of the transport region 256. Larger overall flow rates can be achieved by using a transport region 256 having a larger porosity, decreasing the thickness of the transport region 256, or increasing the surface area of the transport region 256. In one embodiment, with a flow rate requirement of 0.3-1.0 L/min in immersion lithography, pores size of 40-150 μm can be used to cover a 30-150 cm^2 area for immersion fluid 248 recovery. The type and specifications of the porous material also depends on the application and the properties of the immersion fluid 248.

Referring back to Figure 2B, in certain embodiments, the transport region 256 has a limited capacity to absorb the immersion fluid 248. In one embodiment, the immersion fluid system 252 includes a fluid removal system 282 that removes immersion fluid 248 from or near the transport region 256 and that is in fluid communication with the transport region 256 and the removal chamber 276. With this design, the immersion fluid 248 can be captured with the transport region 256 and removed by the fluid removal system 276.

In one embodiment, the fluid removal system 282 removes the immersion fluid 248 from the top first surface 278A of the transport region 256 allowing additional immersion fluid 248 to flow into the bottom, second surface 278B of the transport region 256. For example, the fluid removal system 282 can create a pressure differential across the transport region 256. In one example, the fluid removal system 282 causes the pressure at the first surface 278A to be lower than the pressure at the second surface 278B.

The removal of the immersion fluid 248 can be accomplished in several different ways and a number of embodiments of the fluid removal system 282 are described below.

Figure 2C illustrates that a frame gap 284 exists between (i) the bottom side 270B of the containment frame 264 and the second surface 278B of the transport region 256, and (ii) the wafer 30 and/or the device stage 42 to allow for ease of movement of the device stage 42 and the wafer 30 relative to the containment frame 264. The size of the frame gap 284 can vary. In one embodiment, the frame gap 284 is between approximately 0.1 and 2 mm. In alternative examples, the frame gap 284 can be approximately 0.05, 0.1, 0.2, 0.5, 1, 1.5, 2, 3, or 5 mm.

With this embodiment, most of the immersion fluid 248 is confined within the fluid barrier 254 and most of the leakage around the periphery is scavenged within the narrow frame gap 284 by the transport region 256. In this case, when the immersion fluid 248 touches the transport region 256, it is drawn into the transport region 256 and absorbed. Thus, the transport region 256 inhibits any immersion fluid 248 from flowing outside the ring.

Figure 2D illustrates a cut-away view of portion of another embodiment of an exposure apparatus 10D that is somewhat similar to the embodiment illustrated in Figure 2C. However, in Figure 2D, the device 30D and/or the stage 42D is closer to the bottom side 270BD of the inner side 270CD and/or the outer side 270DD of the containment frame 264D than the second surface 278DB of the transport region 256D. Stated another way, the distance between the bottom side 278BD and the device 30D and/or the stage 42D is less than the distance between the second surface 278DB and the device 30D and/or the stage 42D.

Figure 3A illustrates one embodiment of the immersion fluid source 260. In this embodiment, the immersion fluid source 260 includes (i) a fluid reservoir 386A that retains the immersion fluid 248, (ii) a filter 386B in fluid communication with the fluid reservoir 386A that filters the immersion fluid 248, (iii) an aerator 386C in fluid communication with the filter 386B that removes any air, contaminants, or gas from the immersion fluid 248, (iv) a temperature controller 386D, e.g. a heat exchanger or chiller, in fluid communication with the aerator 386C that controls the temperature of the immersion fluid 248, (v) a pressure source 386E , e.g. a pump, in fluid communication with the temperature controller 386D, and (vi) a flow

controller 386F that has an inlet in fluid communication with the pressure source 386E and an outlet in fluid communication with the nozzle outlets 262 (illustrated in Figure 2C), the flow controller 386F controlling the pressure and flow to the nozzle outlets 262.

Additionally, the immersion fluid source 260 can include (i) a pressure sensor 386G that measures the pressure of the immersion fluid 248 that is delivered to the nozzle outlets 262, (ii) a flow sensor 386H that measures the rate of flow of the immersion fluid 248 to the nozzle outlets 262, and (iii) a temperature sensor 386I that measures the temperature of the immersion fluid 248 to the nozzle outlets 262. The operation of these components can be controlled by the control system 24 (illustrated in Figure 1) to control the flow rate, temperature and/or pressure of the immersion fluid 248 to the nozzle outlets 262. The information from these sensors 386G-386I can be transferred to the control system 24 so that the control system 24 can appropriately adjust the other components of the immersion source 360A to achieve the desired temperature, flow and/or pressure of the immersion fluid 248.

It should be noted that orientation of the components of the immersion fluid source 260 can be varied. Further, one or more of the components may not be necessary and/or some of the components can be duplicated. For example, the immersion fluid source 260 can include multiple pumps, multiple reservoirs, temperature controllers or other components. Moreover, the environmental system 26 can include multiple immersion fluid sources 260.

The rate at which the immersion fluid 248 is pumped into the gap 246 (illustrated in Figure 2B) can vary. In one embodiment, the immersion fluid 248 is supplied to the gap 246 via the nozzle outlets 262 at a rate of between approximately 0.5 liters/min to 2 liters/min. However, the rate can be greater or less than these amounts.

The type of immersion fluid 248 can be varied to suit the design requirements of the apparatus 10. In one embodiment, the immersion fluid 248 is a fluid such as De-gassed, De-ionized water. Alternatively, for example, the immersion fluid 248 can be another type of fluid, such as a per-fluorinated poly ether (PFPE) such as Fomblin oil.

Figure 3B illustrates a first embodiment of the fluid removal system 382B and an illustration of a portion of the fluid barrier 254, the transport region 256, the

wafer 30, and the immersion fluid 248. The fluid removal system 382B is also referred to herein as a pressure system. In one embodiment, the fluid removal system 382B creates and/or applies a transport pressure to the first surface 278A of the transport region 256. In this embodiment, the fluid removal system 382B maintains the transport pressure at the first surface 278A of the transport region 256 so that a pressure differential exists between the first surface 278A and the second surface 278B. In alternative, non-exclusive embodiments, the fluid removal system 382B controls the pressure in the removal chamber 276 so that the transport pressure at the first surface 278A is approximately -10, -100, -500, -1000, -2000, -5000, -7000 or -10,000 Pa gage.

In Figure 3B, the fluid removal system 382B includes (i) a low pressure source 390BA that creates a low chamber pressure in the removal chamber 276, and (ii) a recovery reservoir 390BC that captures immersion fluid 248 from the removal chamber 276. In this embodiment, the low pressure source 390BA can include a pump or vacuum source 390BD, and a chamber pressure regulator 390BE for precisely controlling the chamber pressure in the chamber 276. In alternative, non-exclusive embodiments, for example, the chamber pressure is controlled to be approximately -10, -100, -500, -1000, -2000, -5000, -7000 or -10,000 Pa gage. The chamber pressure regulator 390BE can be controlled by the control system 24 to control the chamber pressure.

Figure 3C illustrates another embodiment of the fluid removal system 382C and an illustration of a portion of the fluid barrier 254, the transport region 256, the wafer 30, and the immersion fluid 248. In this embodiment, the fluid removal system 382C forces a dry removal fluid 396 (illustrated as triangles), e.g. air through the removal chamber 276 and across the top first surface 278A of the transport region 256. The removal fluid 396 will dry the top surface 278A of the transport region 256, pumping immersion fluid 248 out of the transport region 256. The removal fluid 396 can be heated in some cases, improving the flow of the immersion fluid 248 into the dry fluid 396. Stated another way, in one embodiment, the removal fluid 396 is at a removal fluid temperature that is higher than an immersion fluid temperature of the immersion fluid 248.

In Figure 3C, the fluid removal system 382C includes (i) a fluid source 396A of the pressurized drying removal fluid 396, (ii) a temperature controller 396B that controls the temperature of the drying removal fluid 396, (iii) a flow

sensor 396C that measures the flow of the drying removal fluid 396, and (iv) a temperature sensor 396D that measures the temperature of the drying removal fluid 396. The fluid source 396A can include a pump controlled by the control system 24 and the temperature controller 396B can be a heater that is controlled by the control system 24.

Figure 3D illustrates yet another embodiment of the fluid removal system 382D and an illustration of a portion of the fluid barrier 254, the transport region 256, the wafer 30, and the immersion fluid 248. In this embodiment, the transport region 256 is extended outside the fluid barrier 254. Further, the fluid removal system 382C includes a heat source 397 that directs a heated fluid 396F (illustrated as triangles) at the first surface 278A of the transport region 256, causing the immersion fluid 248 to boil out of the transport region 256 and be captured.

It should be noted that orientation of the components of the fluid removal systems 382B and 382C illustrated in Figures 3B-3D can be varied. Further, one or more of the components may not be necessary and/or some of the components can be duplicated. For example, each of the fluid removal systems 382B, 382C, 382D can include multiple pumps, multiple reservoirs, valves, or other components. Moreover, the environmental system 26 can include multiple fluid removal systems 382B, 382C, 382D.

Figure 4 is an enlarged view of a portion of another embodiment of the environmental system 426, a portion of the wafer 30, and a portion of the device stage 42. In this embodiment, the environmental system 426 is somewhat similar to the corresponding component described above and illustrated in Figures 2A-2C. However, in this embodiment, the transport region 456 is slightly different. In particular, in this embodiment, the passages 480 (only two are illustrated) in the substrate 475 of the transport region 456 are a plurality of spaced apart transport apertures that extend substantially transversely through the substrate 475 between the first surface 478A and the second surface 478B.

In this embodiment, for example, the substrate 475 can be made of a material such as glass or other hydrophilic materials. In one embodiment, the transport apertures 480 can have a diameter of between approximately 0.1 and 0.2 mm. However, in certain embodiments, the transport apertures can be larger or smaller than these amounts

With this design, for example, one or more of the fluid removal systems 382B, 382C (illustrated in Figure 3B and 3C) can be used to apply a vacuum or partial vacuum on the transport apertures 480. The partial vacuum draws the immersion fluid 248 through the transport region 456.

Figure 5A is a cut-away view of a portion of another embodiment of the exposure apparatus 510, including the optical assembly 516, the device stage 542, and the environmental system 526. Figure 5A also illustrates the wafer 30, the gap 546, and that the immersion fluid 548 fills the gap 546. Figure 5B illustrates an enlarged portion of the Figure 5A taken on line 5B-5B.

In this embodiment, the environmental system 526 again includes an immersion fluid system 552, a fluid barrier 554, and a transport region 556 that are somewhat similar to the corresponding components described above. In this embodiment, the fluid barrier 554 includes a containment frame 564 that forms a chamber 557 around the gap 546, and a frame support 568 that connects and supports the containment frame 564 to the apparatus frame 12. However, in this embodiment, the containment frame 564 includes (i) an annular shaped first channel 581 that defines a nozzle outlet 562 that is in fluid communication with an immersion fluid source 560 of the immersion fluid system 552; (ii) an annular shaped second channel 583, (iii) an annular shaped third channel 585, and (iv) an annular shaped fourth channel 587 for receiving the transport region 556. In this embodiment, the channels 581, 583, 585, 587 are approximately concentric and are centered about the optical assembly 516. Further, in this embodiment, the second channel 583 encircles the first channel 581, the third channel 585 encircles the second channel 583, and the fourth channel 587 encircles the third channel 585. However, the shape, orientation, and/or position of the channels 581, 583, 585, 587 can be changed.

In one embodiment, the immersion fluid system 552 provides the immersion fluid 548 to the first channel 581 and the nozzle outlet 562 that is released into the chamber 557. The transport region 556 cooperates with the containment frame 564 to form a removal chamber 576 next to and above the transport region 556. Moreover, the transport region 556 includes a first surface 578A that is adjacent the removal chamber 576 and an opposed second surface 578B is adjacent to the device 30 and the gap 546.

In this embodiment, the third channel 585 is in fluid communication with a first removal system 582A. In one embodiment, the first removal system 582A creates a vacuum or partial vacuum in the third channel 585 that pulls and/or draws the immersion fluid 548 into the third channel 585. For example, in alternative non-exclusive embodiments, the first removal system 582A can maintain the pressure in the third channel 585 at approximately -10, -100, -500, -1000, -2000, -5000, -7000 or -10,000 Pa gage.

Further, in this embodiment, the fourth channel 587 is in fluid communication with a second removal system 582B. In this embodiment, the second removal system 582 removes the immersion fluid 548 from the top first surface 578A of the transport region 556 allowing additional immersion fluid 548 to flow into the bottom, second surface 578B of the transport region 556.

In one embodiment, the design of the first removal system 582A can be somewhat similar to the design of one of the removal systems 382B, 382C illustrated in Figures 3B-3D and/or the design of the second removal system 582B can be somewhat similar to one of the designs illustrated in Figures 3B-3D.

In one embodiment, the majority of the immersion fluid 548 exiting from the gap 546 is recovered through the third channel 585. For example, the third channel 585 can recover between approximately 80-90 percent of the immersion fluid 548 recovered from the gap 546. In alternative embodiments, the third channel 585 can recover at least approximately 50, 60, 70, 80, or 90 percent of the immersion fluid 548 recovered from the gap 546. With this design, the fourth channel 587 can be used to capture the immersion fluid 548 not captured by the third channel 585.

Additionally, in one embodiment, the environmental system 526 includes a pressure controller 591 that can be used to control the pressure in the gap 546. In one embodiment, the pressure controller 591 can cause the pressure in the gap 546 to be approximately equal to the pressure outside of the gap 546. For example, in one embodiment, the second channel 583 defines the pressure controller 591. In this embodiment, the second channel 583 is open to the atmospheric pressure and is positioned inside the periphery of third channel 585. With this design, the negative pressure (vacuum or partial vacuum) in the third channel 585 will not strongly influence the pressure between the optical assembly 516 and the wafer 30.

Alternatively, for example, a control pressure source 583 can deliver a control fluid 595 (illustrated as triangles) to the second channel 583 that is released into the gap 546. In one embodiment, the control fluid 595 can be a gas that is not easily absorbed by the immersion fluid 548. For example, if the immersion fluid 548 is water, the control fluid 595 can be water. If the immersion fluid 548 does not absorb the control fluid 595 or otherwise react to it, the chances of bubble formation on the surface of the wafer 30 can be reduced.

In yet another embodiment, the environmental system 526 can include a device for creating a fluid bearing (not shown) between the containment frame 564 and the wafer 30 and/or the device stage 542. For example, the containment frame 564 can include one or more bearing outlets (not shown) that are in fluid communication with a bearing fluid source (not shown) of a bearing fluid (not shown). In this embodiment, the bearing fluid source provides pressurized fluid to the bearing outlet to create the aerostatic bearing. The fluid bearings can support all or a portion of the weight of the containment frame 564.

It should be noted that in each embodiment, additional transport regions can be added as necessary.

Semiconductor devices can be fabricated using the above described systems, by the process shown generally in Figure 6A. In step 601 the device's function and performance characteristics are designed. Next, in step 602, a mask (reticle) having a pattern is designed according to the previous designing step, and in a parallel step 603 a wafer is made from a silicon material. The mask pattern designed in step 602 is exposed onto the wafer from step 603 in step 604 by a photolithography system described hereinabove in accordance with the present invention. In step 605 the semiconductor device is assembled (including the dicing process, bonding process and packaging process), finally, the device is then inspected in step 606.

Figure 6B illustrates a detailed flowchart example of the above-mentioned step 604 in the case of fabricating semiconductor devices. In Figure 6B, in step 611 (oxidation step), the wafer surface is oxidized. In step 612 (CVD step), an insulation film is formed on the wafer surface. In step 613 (electrode formation step), electrodes are formed on the wafer by vapor deposition. In step 614 (ion implantation step), ions are implanted in the wafer. The above mentioned steps

611 - 614 form the preprocessing steps for wafers during wafer processing, and selection is made at each step according to processing requirements.

At each stage of wafer processing, when the above-mentioned preprocessing steps have been completed, the following post-processing steps are implemented. During post-processing, first, in step 615 (photoresist formation step), photoresist is applied to a wafer. Next, in step 616 (exposure step), the above-mentioned exposure device is used to transfer the circuit pattern of a mask (reticle) to a wafer. Then in step 617 (developing step), the exposed wafer is developed, and in step 618 (etching step), parts other than residual photoresist (exposed material surface) are removed by etching. In step 619 (photoresist removal step), unnecessary photoresist remaining after etching is removed.

Multiple circuit patterns are formed by repetition of these preprocessing and post-processing steps.

While the particular exposure apparatus 10 as shown and disclosed herein is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

What is claimed is:

1. An apparatus, comprising:

a stage configured to hold a work piece;

a reticle stage configured to hold a reticle that defines an image;

a projection system including an illumination source and an optical element, the projection system configured to project the image defined by reticle into an exposure region on the work piece;

a gap between the optical element and the work piece, the gap configured to be filled with an immersion fluid; and

a porous material, positioned adjacent the gap, the porous material including a plurality of passages for collecting immersion fluid exiting the gap.

2. The apparatus of claim 1, wherein the porous material substantially surrounds the gap.

3. The apparatus of claim 1, further comprising a pressure system used to create a pressure differential across the porous material, the pressure differential acting to pull the immersion fluid through the porous material.

4. The apparatus of claim 1, wherein the porous material comprises one of the following a wick or a mesh material.

5. The apparatus of claim 1, wherein the plurality of passages of the porous material is aided by capillary action for collecting the immersion fluid exiting the gap.

6. The apparatus of claim 1 further comprising a fluid removal system that removes immersion fluid from near the porous material.

7. The apparatus of claim 6 wherein the porous material has a first surface, and a second surface that is positioned near the work piece, and wherein the fluid removal system controls the pressure at the first surface so that pressure at the first surface is below the pressure at the second surface.

8. The apparatus of claim 1 further comprising a pressure controller for controlling the pressure in the gap.

9. The apparatus of claim 1 further comprising a control pressure source that delivers a control fluid to the gap that is not easily absorbed by the immersion fluid.

10. An apparatus, comprising:

a stage configured to hold a work piece;

a reticle stage configured to hold a reticle that defines an image;

a projection system including an illumination source and an optical element, the projection system configured to project the image defined by reticle into an exposure region on the work piece;

a gap between the optical element and the work piece, the gap configured to be filled with an immersion fluid; and

a transport region positioned adjacent the gap, the transport region having a first surface, a second surface that is position near the work piece, and a plurality of passages that extend between the surfaces for collecting immersion fluid exiting the gap.

11. The apparatus of claim 10, wherein the transport region substantially surrounds the gap.

12. The apparatus of claim 10, further comprising a fluid removal system that creates a pressure differential across the transport region, the pressure differential acting to pull the immersion fluid through the transport region.

13. The environmental system of claim 12 wherein the fluid removal system controls the pressure at the first surface so that pressure at the first surface is below the pressure at the second surface.

14. The apparatus of claim 10 further comprising a pressure controller for controlling the pressure in the gap.

15. The apparatus of claim 10 further comprising a control pressure source that delivers a control fluid to the gap that is not easily absorbed by the immersion fluid.

16. An apparatus, comprising:

a stage configured to hold a work piece;

a reticle stage configured to hold a reticle that defines an image;

a projection system including an illumination source and an optical element, the projection system configured to project the image defined by reticle into an exposure region on the work piece;

a gap between the optical element and the work piece, the gap configured to be filled with an immersion fluid;

a transport region positioned adjacent the gap, the transport region including a first surface positioned away from the work piece, a second surface positioned adjacent the work piece, and a plurality of passages for collecting immersion fluid exiting the gap; and

a fluid removal system that is in fluid communication with the transport region, the fluid removal system maintaining a pressure differential across the transport region between the surfaces.

17. The apparatus of claim 16, wherein the transport region substantially surrounds the gap.

18. The apparatus of claim 16, wherein the transport region includes a porous material that collects immersion fluid by capillary action.

19. The apparatus of claim 18, wherein the porous material comprises one of the following a wick or a mesh material.

20. The apparatus of claim 16 wherein the fluid removal system maintains the pressure near the first surface below the pressure at the second surface.

21. The apparatus of claim 16 wherein the transport region includes a plurality of spaced apart transport apertures which extend through the transport region between the surfaces.

22. A method for transferring an image to a work piece, the method comprising the steps of:

holding a reticle with a reticle stage;

providing an optical assembly that projects the image onto the work piece;

holding the work piece with a stage, the work piece being spaced apart a gap from the optical assembly;

directing an immersion fluid into the gap; and

positioning a porous material adjacent to the gap, the porous material including a plurality of passages for collecting immersion fluid exiting the gap.

23. The method of claim 22 further comprising the step of creating a pressure differential across the porous material with a pressure system, the pressure differential acting to pull the immersion fluid through the porous material.

24. The method of claim 22 wherein the plurality of passages of the porous material is aided by capillary action for collecting the immersion fluid exiting the gap.

25. A method for transferring an image to a work piece, the method comprising the steps of:

holding a reticle with a reticle stage;

providing an optical assembly that projects the image onto the work piece;

holding the work piece with a stage, the work piece being spaced apart a gap from the optical assembly;

directing an immersion fluid into the gap; and

positioning a transport region adjacent to the gap, the transport region including a first surface positioned away from the work piece, a second surface positioned adjacent to the work piece, and a plurality of passages that extend between the surfaces for collecting immersion fluid exiting the gap.

26. The method of claim 25 further comprising the step of creating a pressure differential across the transport region with a pressure system, the pressure differential acting to pull the immersion fluid through the transport region.

27. A method for transferring an image to a work piece, the method comprising the steps of:

holding a reticle with a reticle stage;

providing an optical assembly that projects the image onto the work piece;

holding the work piece with a stage, the work piece being spaced apart a gap from the optical assembly;

directing an immersion fluid into the gap;

positioning a transport region adjacent to the gap, the transport region including a first surface positioned away from the work piece, a second surface positioned adjacent to the work piece, and a plurality of passages for collecting immersion fluid exiting the gap; and

creating a pressure differential across the transport region between the surfaces.

28. An immersion lithography apparatus comprising:

a stage configured to hold a work piece;

a projection system including an illumination source and an optical element, the projection system configured to project an image to an exposure region on the work piece in a lithography process;

a gap configured to be filled with an immersion fluid, the gap being defined between the optical element and the work piece in the lithography process; and

a transport region positioned adjacent the gap, the transport region having a wick structure to collect the immersing fluid in the gap.

29. The immersion lithography apparatus according to claim 28, wherein the transport region includes a porous material.

30. The immersion lithography apparatus according to claim 28, wherein the immersion fluid is drawn into the transport region with capillary forces.

31. The immersion lithography apparatus according to claim 30, wherein the transport region has passages which are small enough so that the capillary forces draw the immersion fluid into the transport region.

32. The immersion lithography apparatus according to claim 28, wherein the transport region has passages which are small enough so that capillary forces draw the immersion fluid into the transport region.

33. The immersion lithography apparatus according to claim 28, wherein the transport region substantially surrounds the gap.

34. The immersion lithography apparatus according to claim 33, wherein the transport region inhibits the immersion fluid from leaking.

35. The immersion lithography apparatus according to claim 33, further comprises a supply nozzle to supply the immersion fluid, the supply nozzle being arranged inside of the transport region.

36. The immersion lithography apparatus according to claim 28, further comprises a fluid removal system to pull the immersion fluid through the transport region.

37. A device manufacturing method for manufacturing a micro-device using a lithography process, wherein the lithography process utilizes the immersion lithography apparatus of claim 28.

1/13

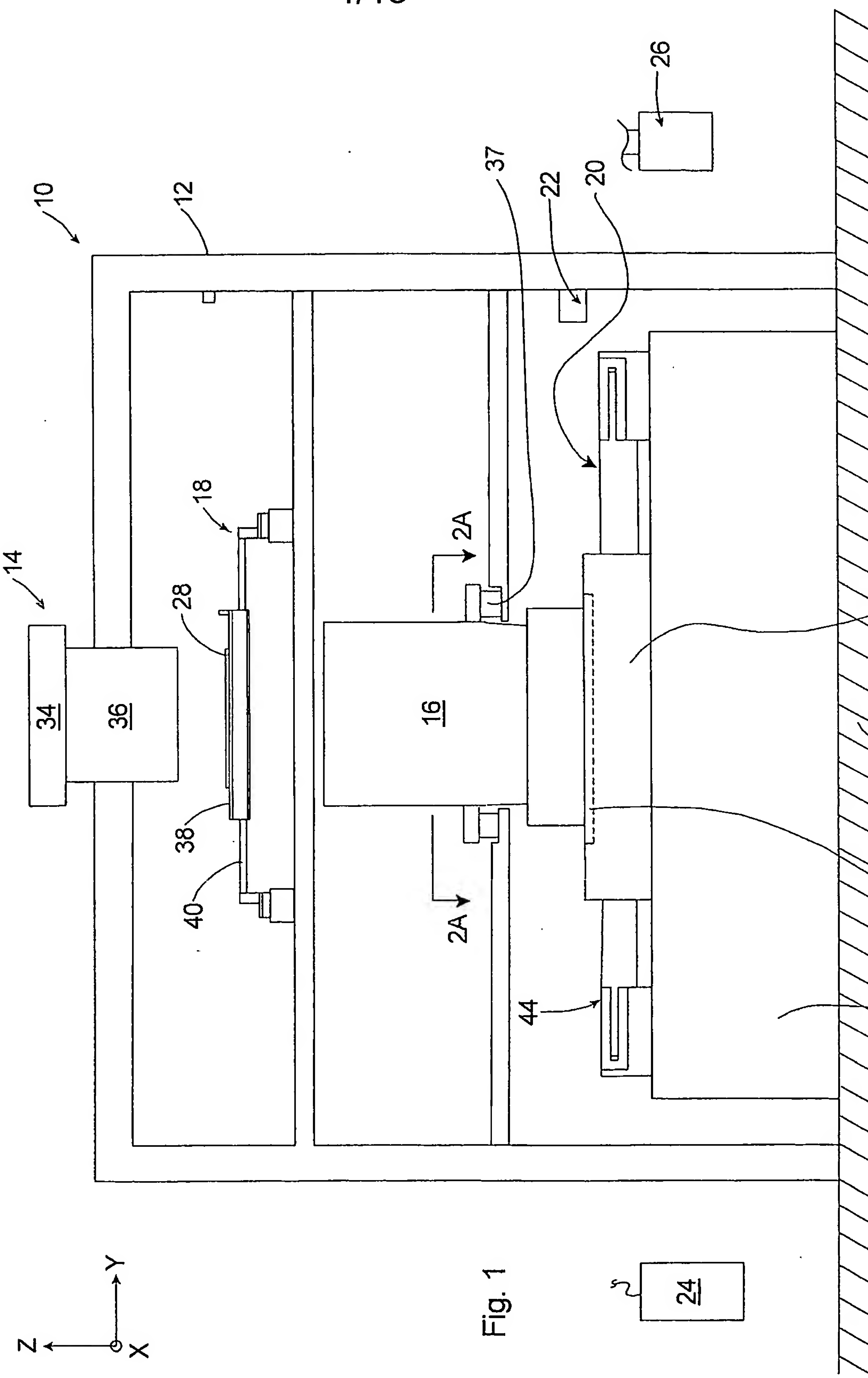


Fig. 1

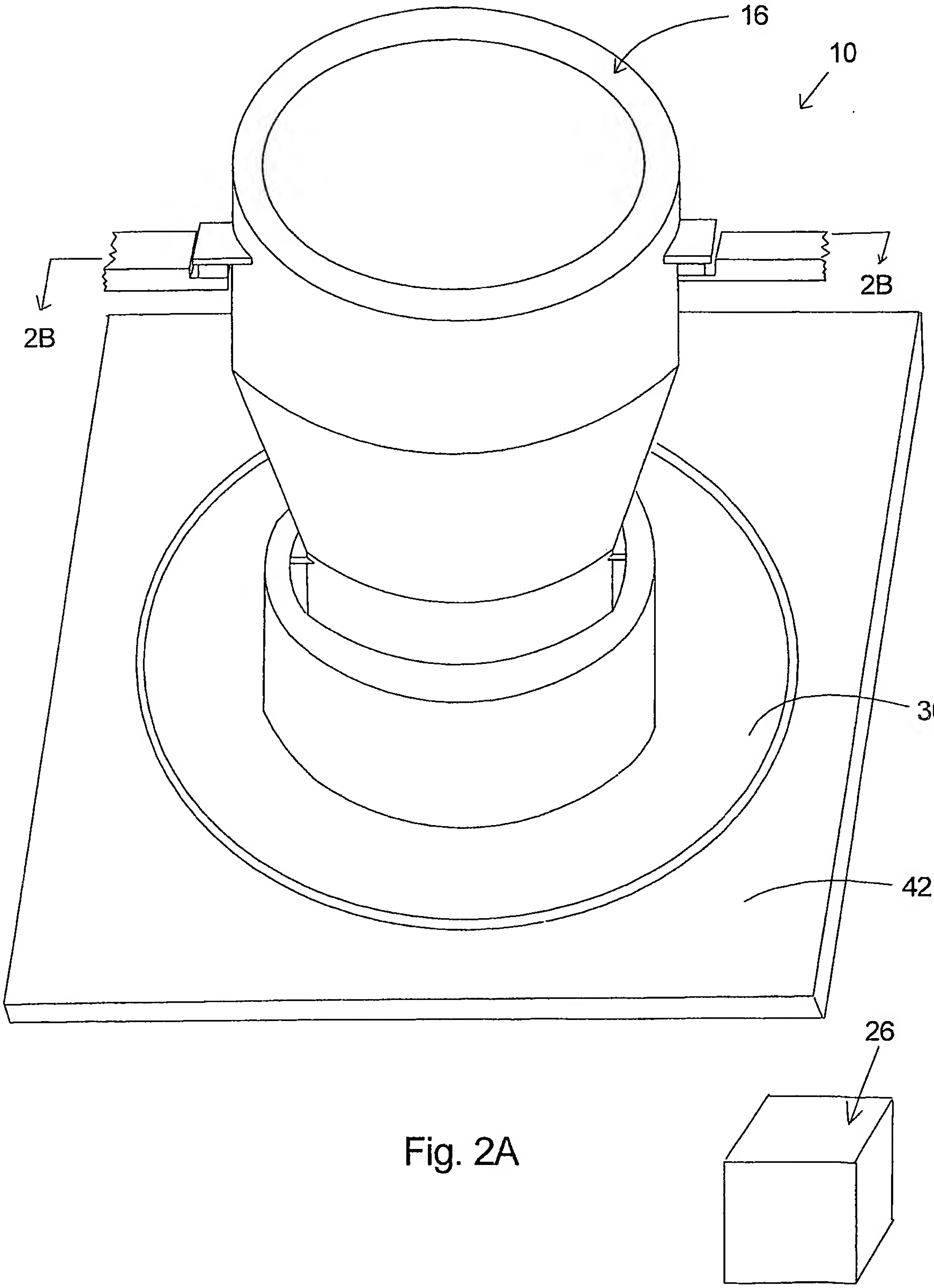


Fig. 2A

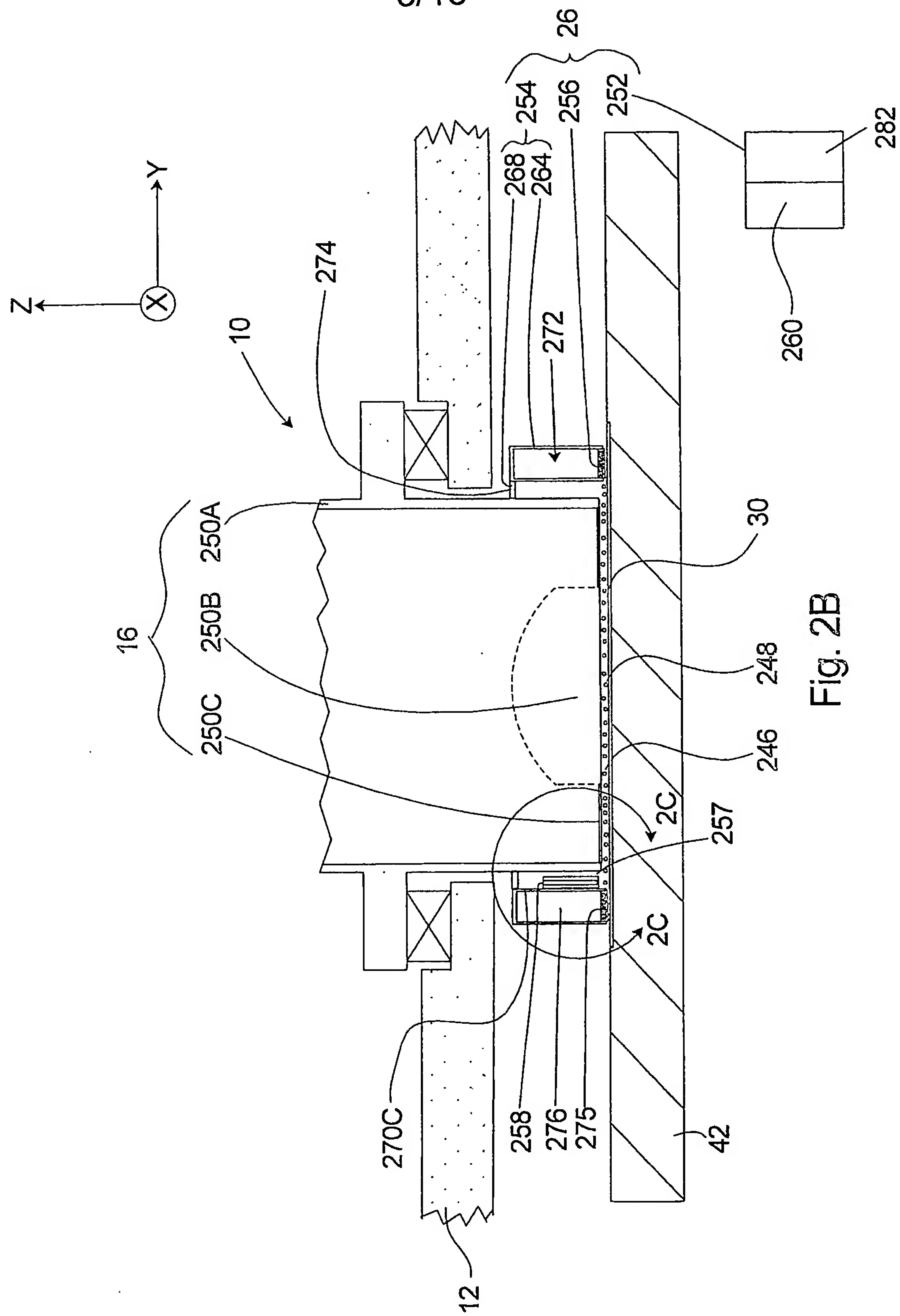

26
254
256
252
282
268
264
260
274
272
10
Y
Z
X
16
250A
250B
250C
30
248
246
2C
257
2C
270C
258
276
275
42
12

Fig. 2B

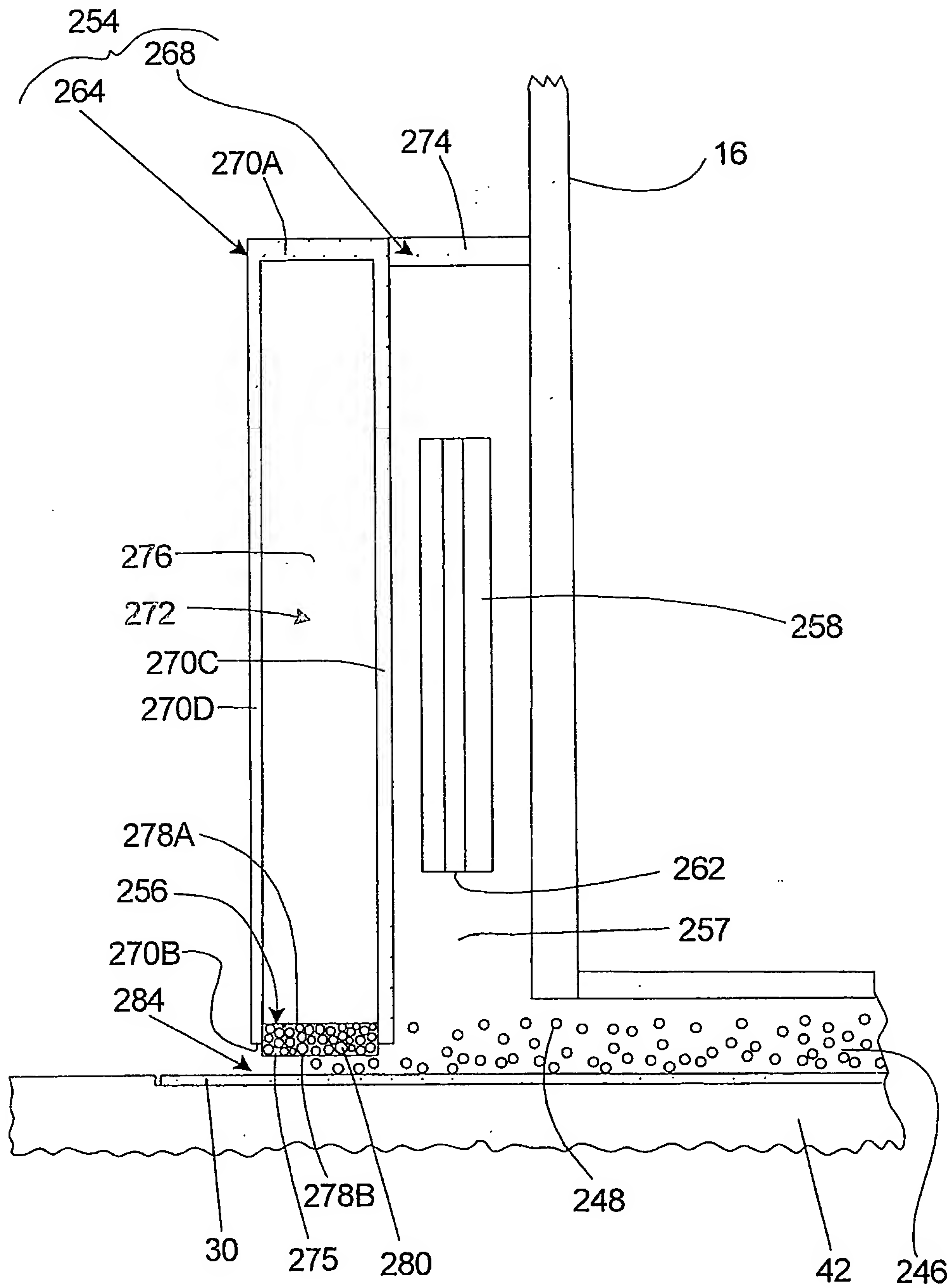

254
268
264
270A
274
16
276
272
270C
270D
258
278A
262
256
257
270B
284
248
278B
30
275
280
42
246

Fig. 2C

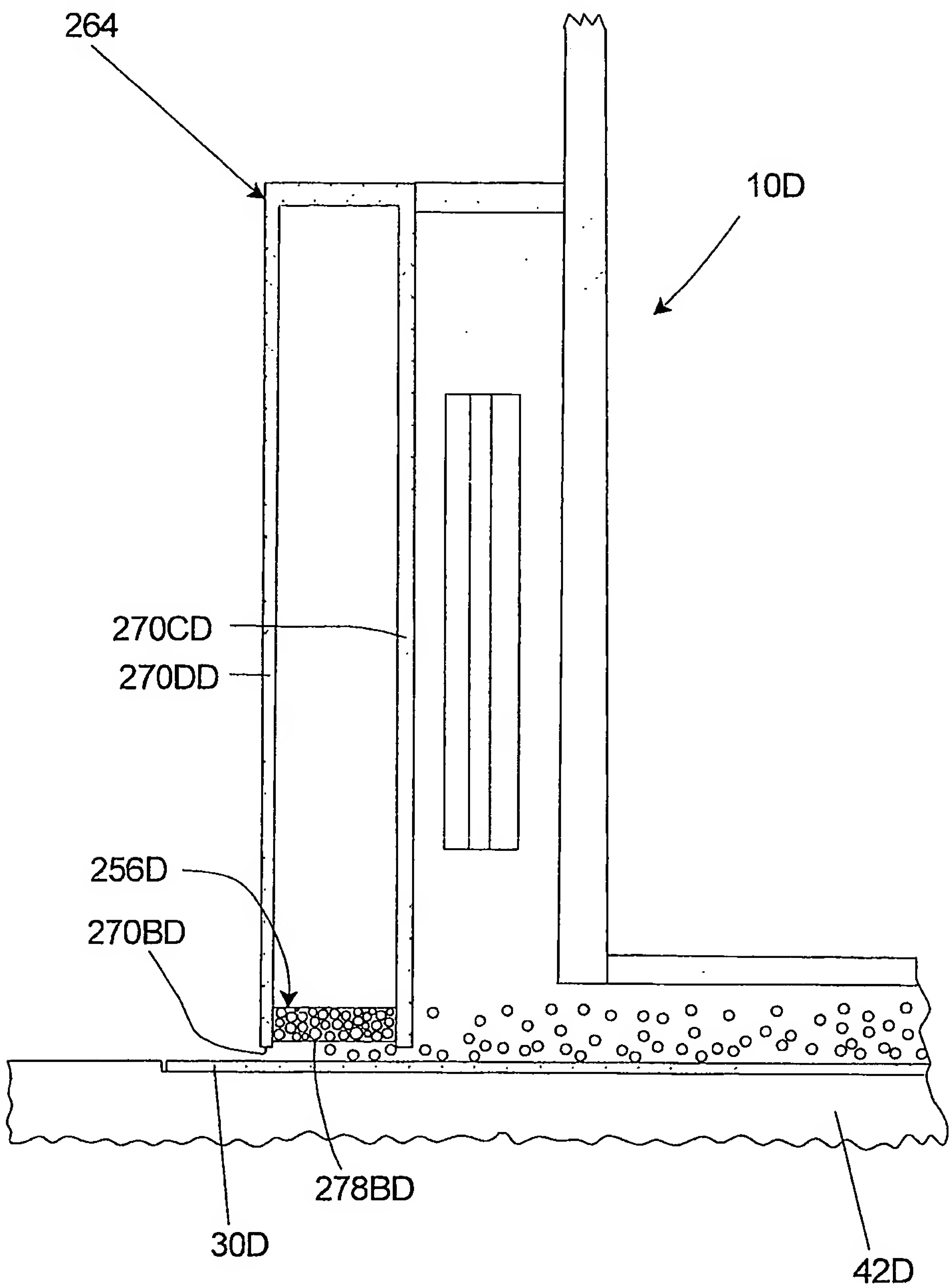


Fig. 2D

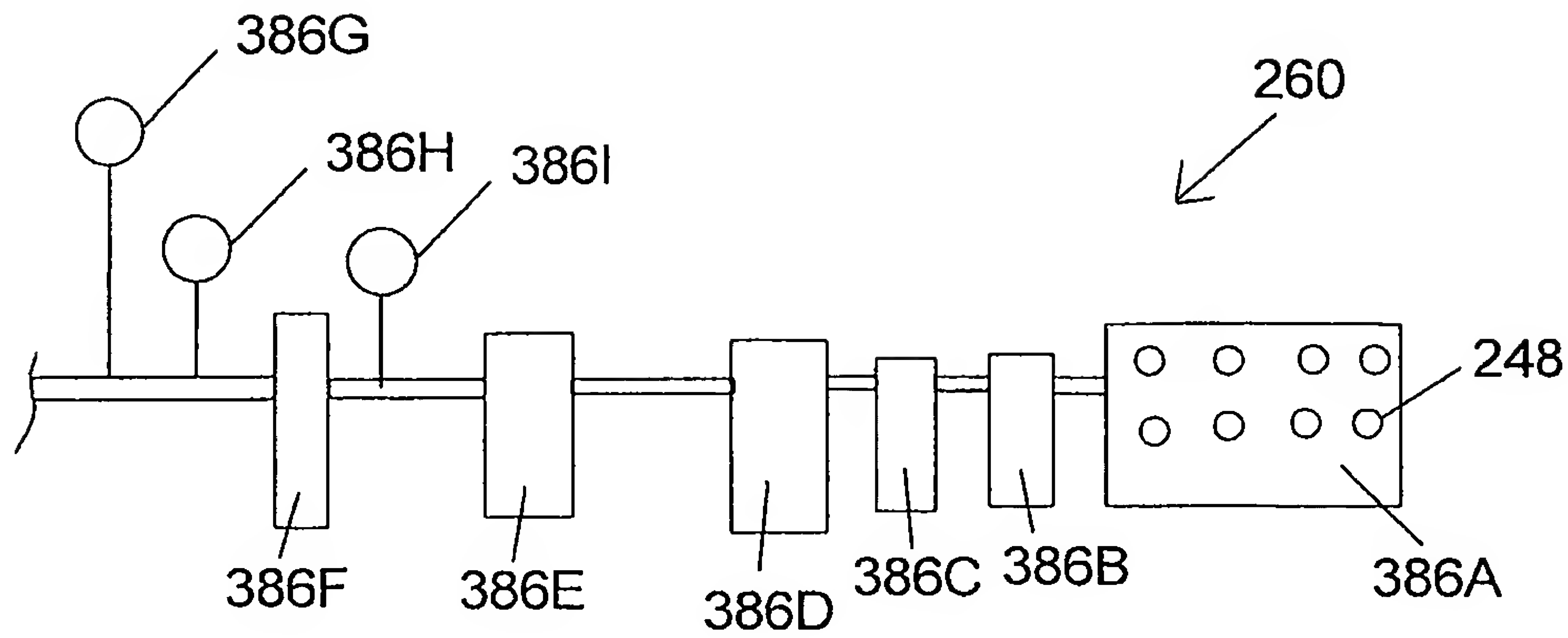

386G
260
386H
386I
248
386F
386E
386D
386C
386B
386A

Fig. 3A

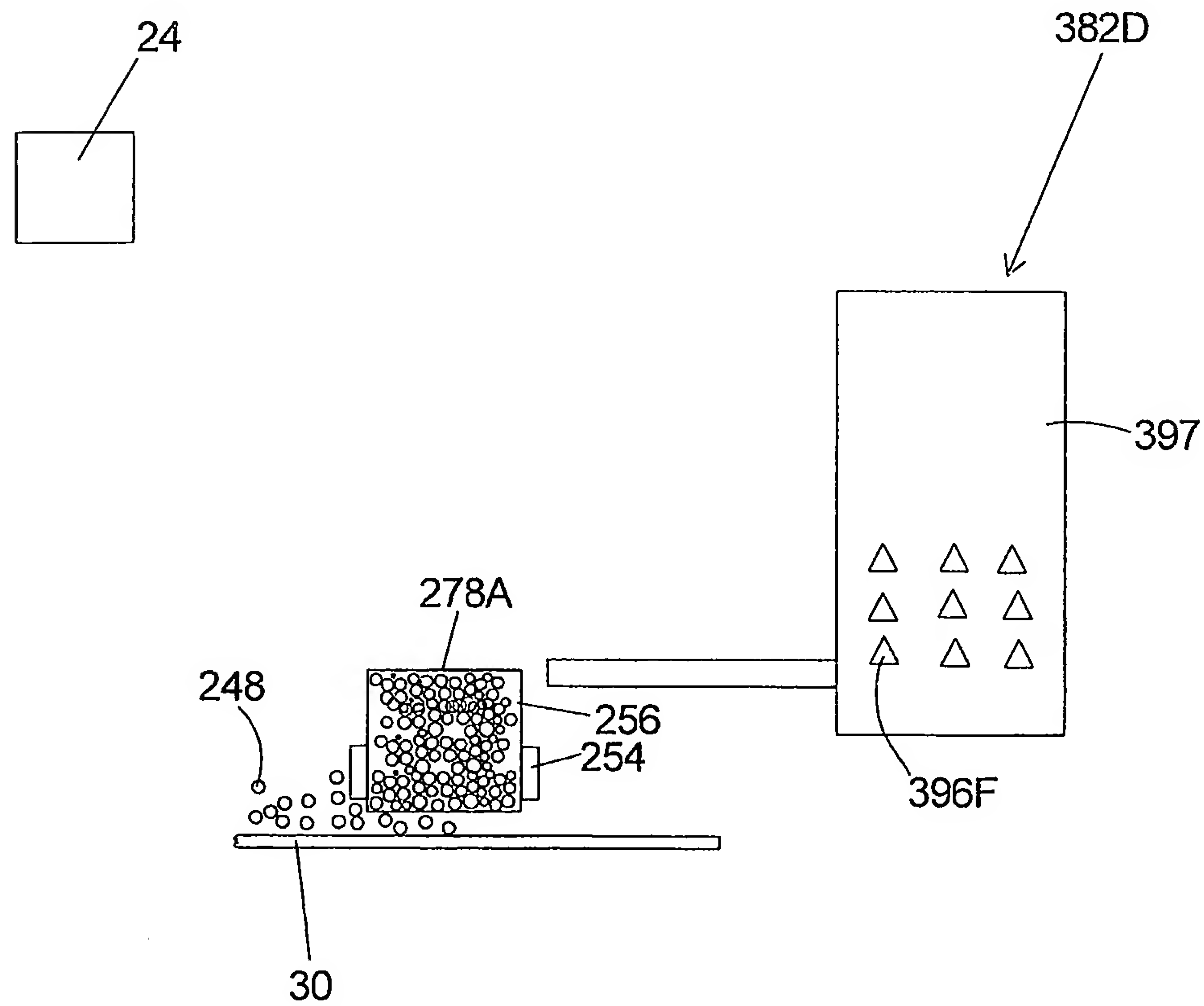

24
382D
397
278A
248
256
254
396F
30

Fig. 3D

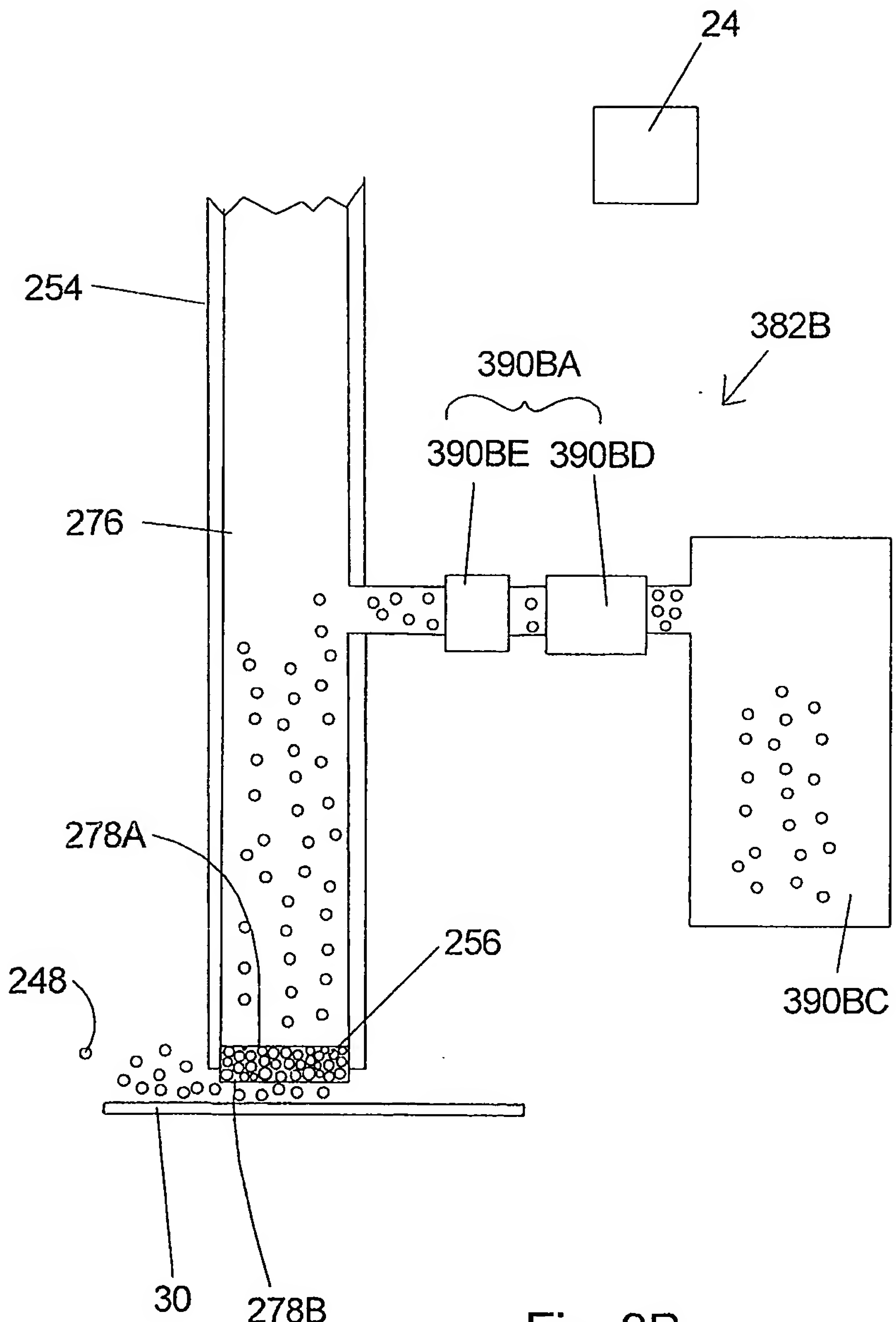


Fig. 3B

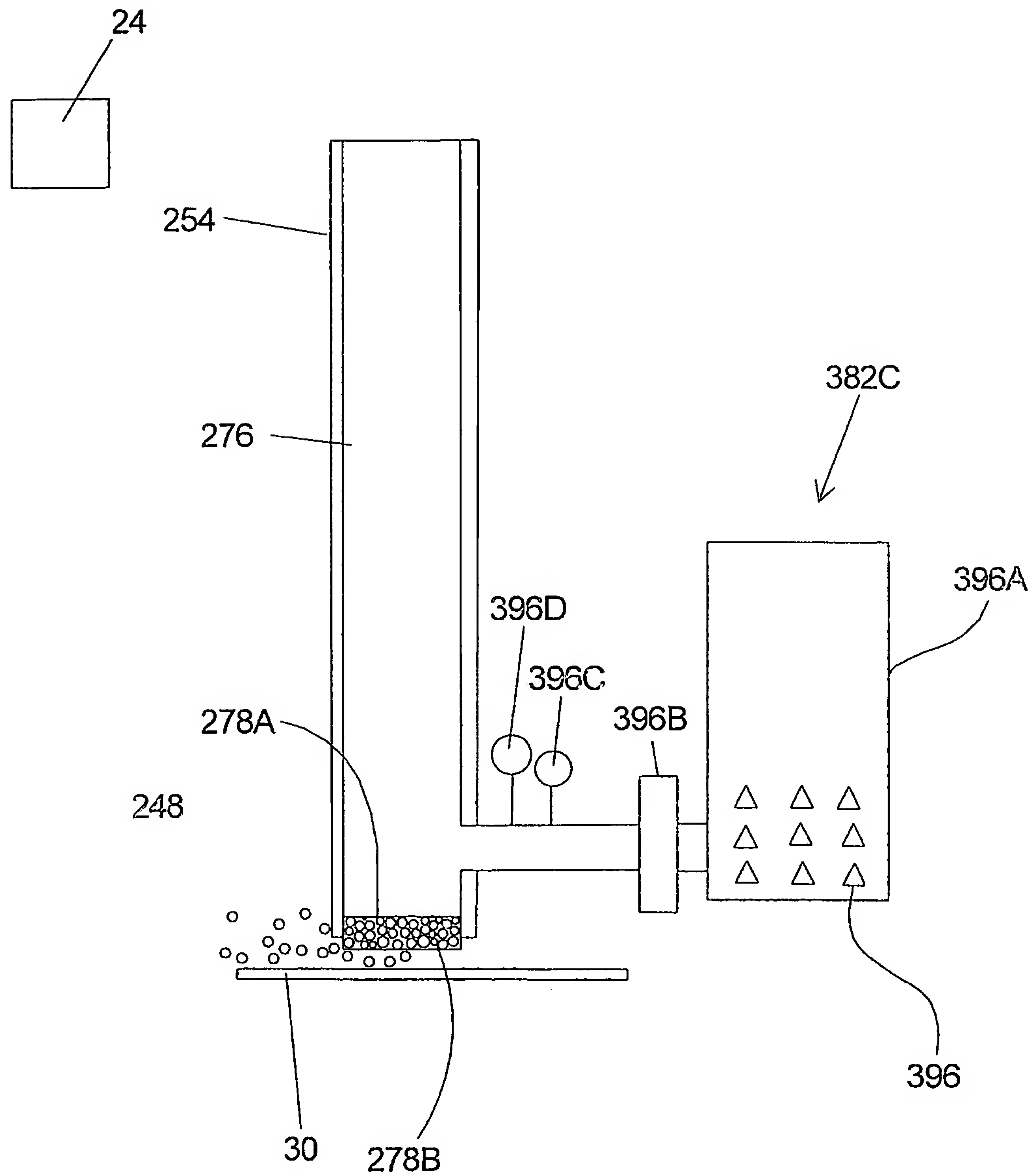


Fig. 3C

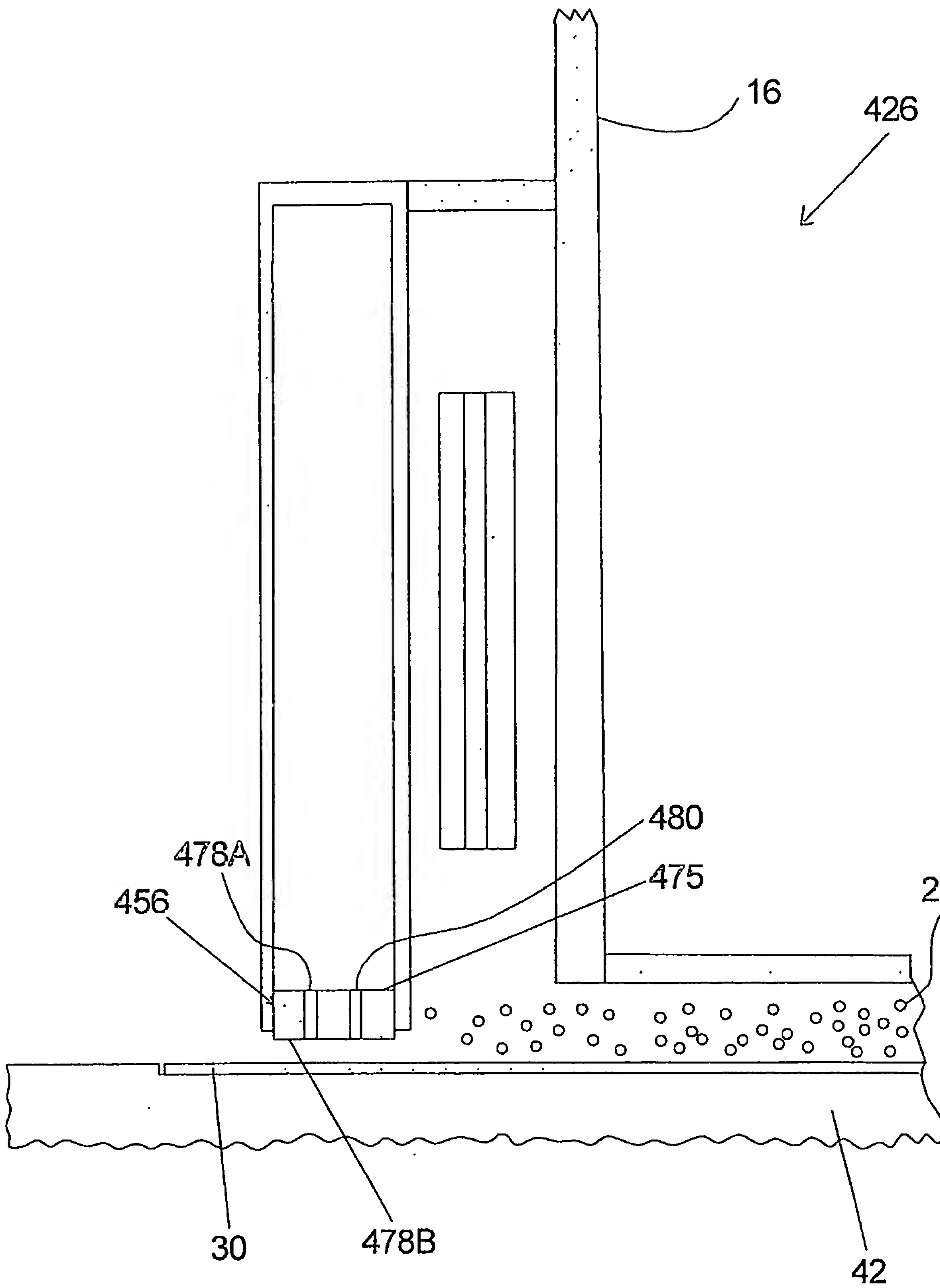


Fig. 4

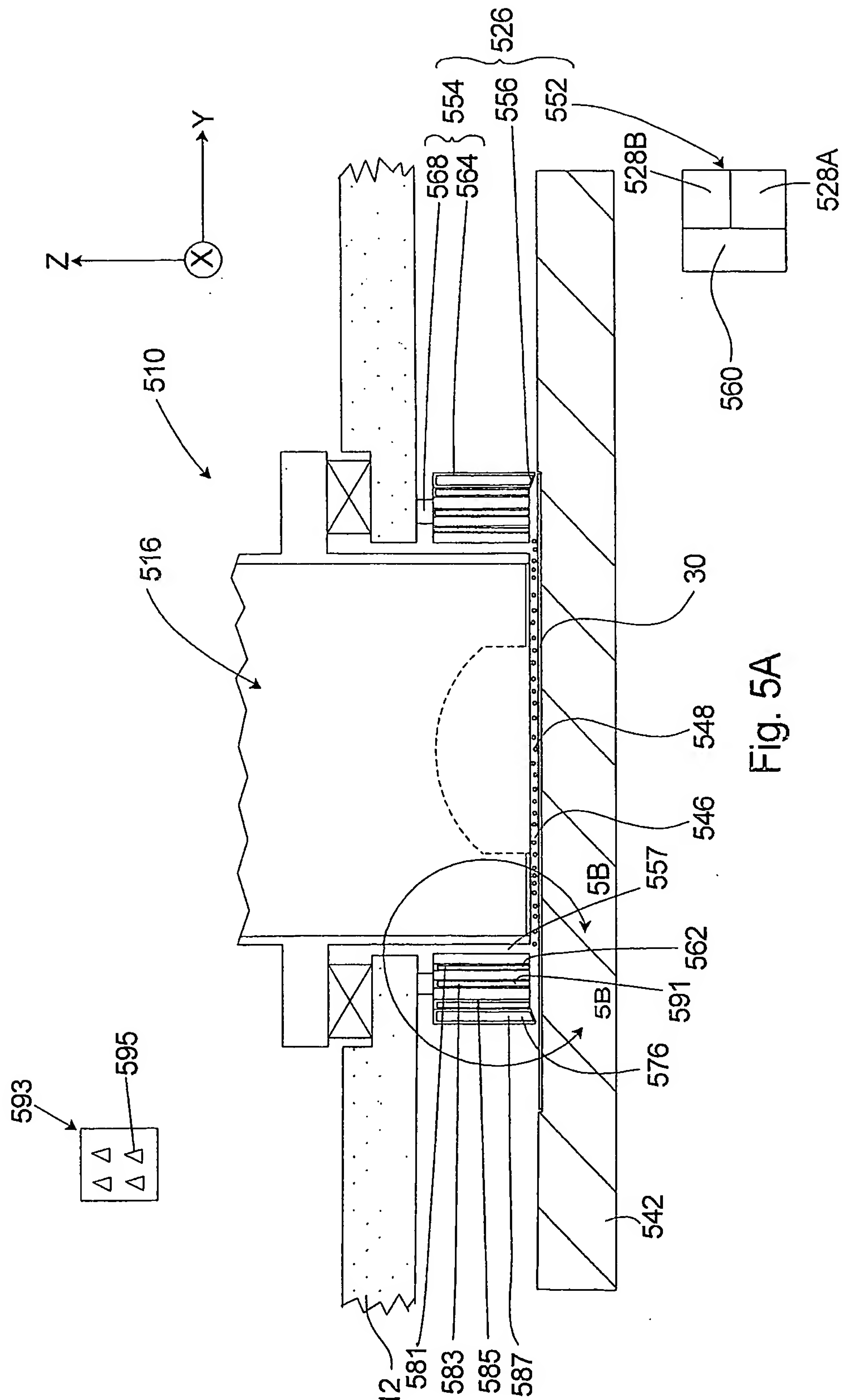

526
554
556
552
568
564
Y
Z
X
528B
528A
560
510
516
30
548
546
5B
557
562
591
5B
576
593
595
542
12
581
583
585
587

Fig. 5A

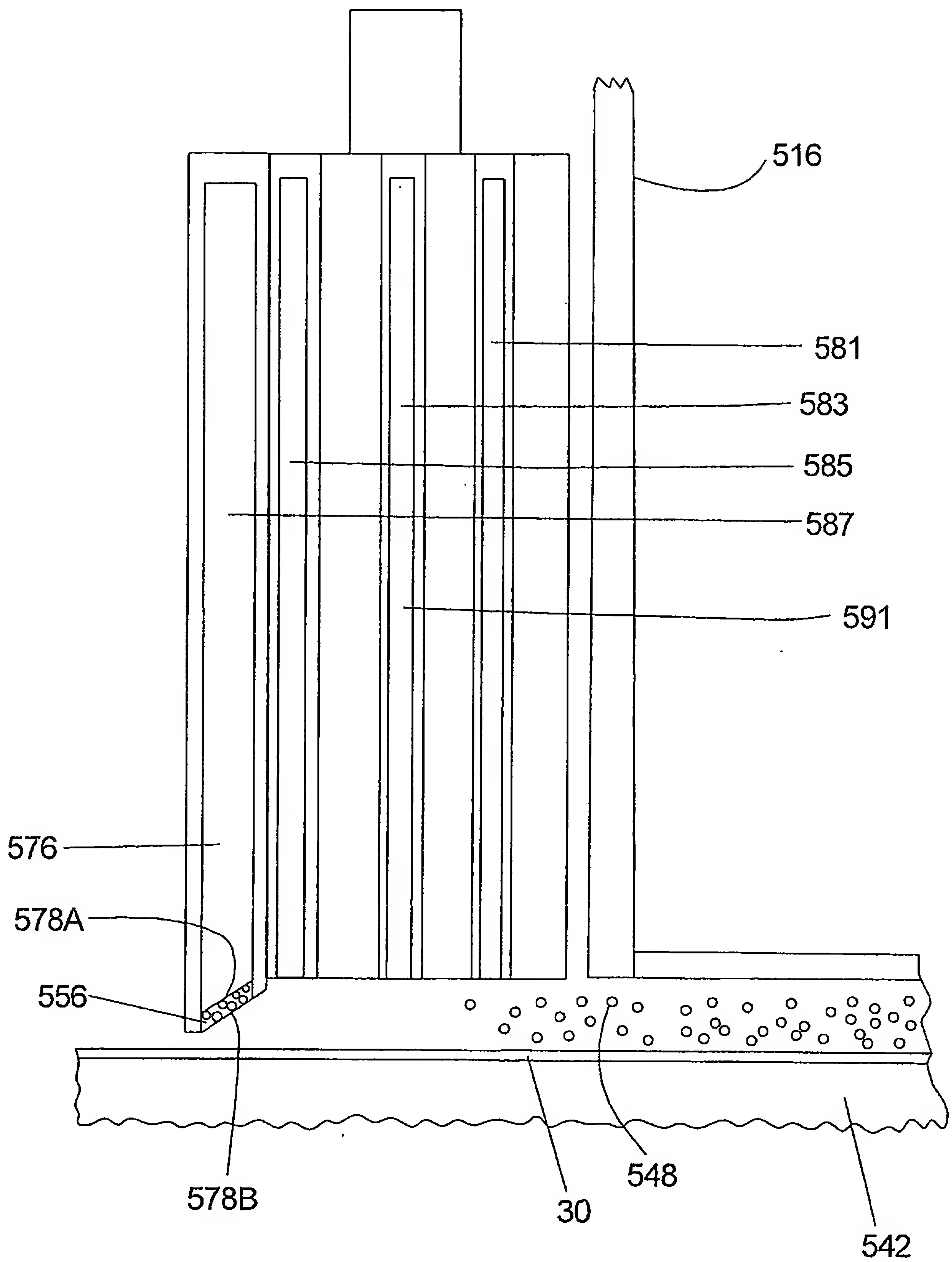


Fig. 5B

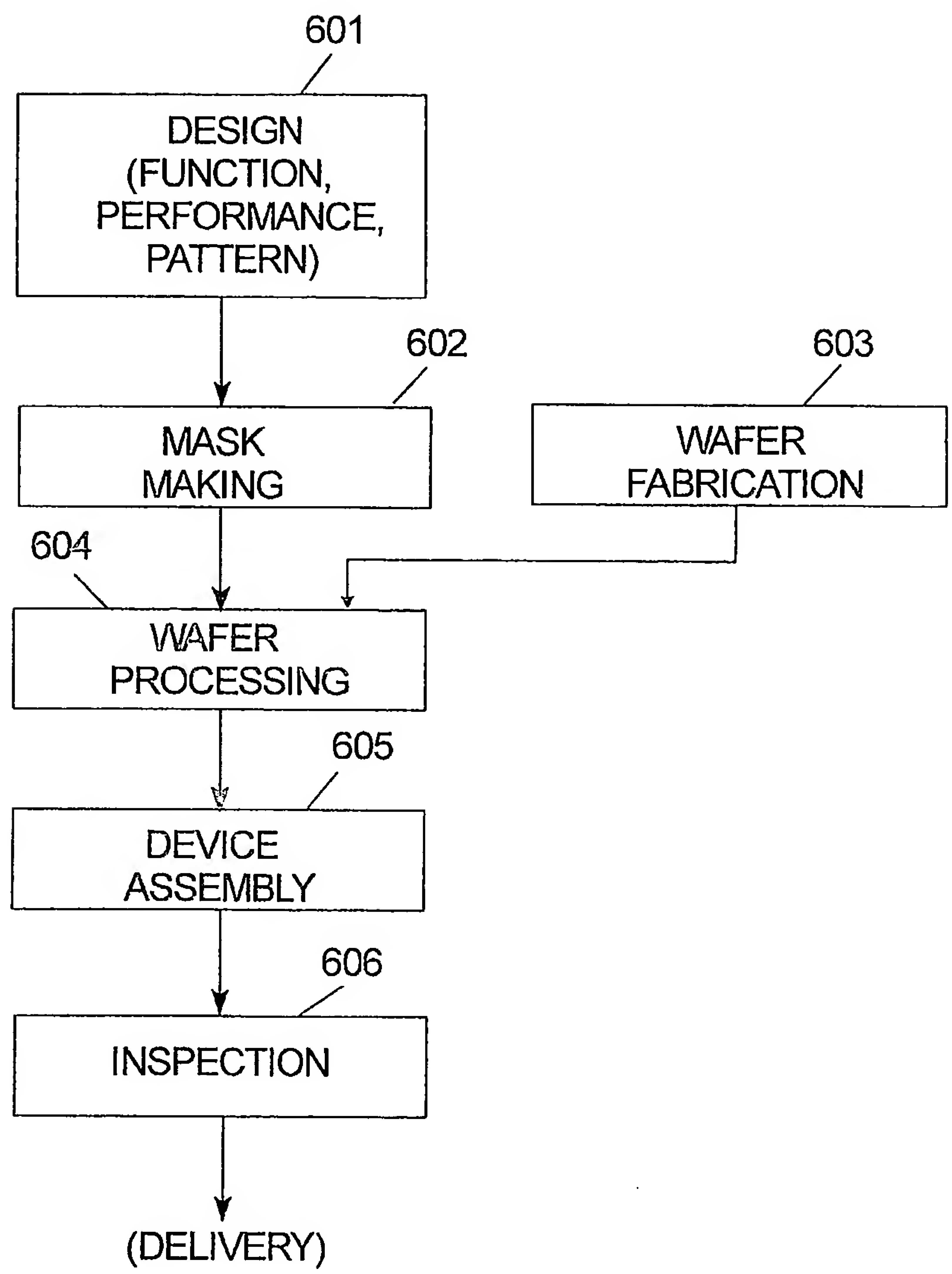

601
DESIGN (FUNCTION, PERFORMANCE, PATTERN)
602
MASK MAKING
603
WAFER FABRICATION
604
WAFER PROCESSING
605
DEVICE ASSEMBLY
606
INSPECTION
(DELIVERY)

Fig. 6A

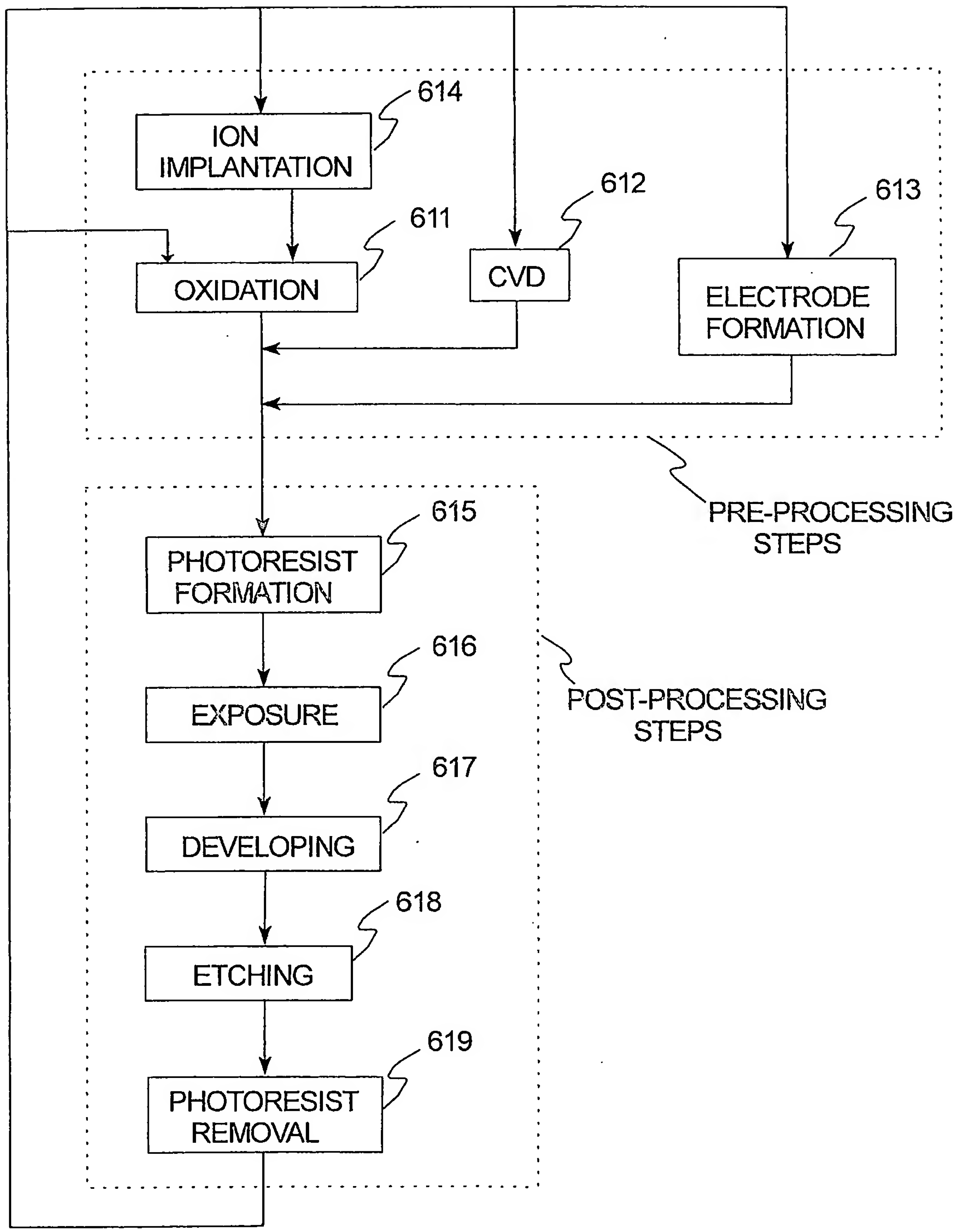

614
ION IMPLANTATION
612
613
611
OXIDATION
CVD
ELECTRODE FORMATION
PRE-PROCESSING STEPS
615
PHOTORESIST FORMATION
616
EXPOSURE
POST-PROCESSING STEPS
617
DEVELOPING
618
ETCHING
619
PHOTORESIST REMOVAL

Fig. 6B